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TELEROBOTIC CONTROLLER DEVELOPMENT

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ABSTRACT

Telerobotic experiments can be performed with existing technology on the orbiter to demonstrate the feasibility to perform supervised robotic material handling and positioning functions in space. To meet NASA's Space Station's needs and growth, MDAC has developed a modular and generic approach to robotic control which provides near term implementation with low development cost and capability for growth to more autonomous systems. This effort uses the MDAC developed, vision based, robotic controller and compliant hand integrated with the RMS arm on orbiter. A description of the hardware and its system integration will be presented.

A ground demonstration of this system will be performed at the Manipulator Development Facility at NASA-JSC using a full size, 1 G version of the orbiter RMS arm. Details of this program will be presented.

INTRODUCTION

The objective of the MDAC/NASA Robotic Tracker demonstration using the Manipulator Development Facility (MDF) arm at the Johnson Space Center is to functionally demonstrate the technology readiness of telerobotics (supervised autonomy) to perform approach, positioning, engagement, and assembly under man supervised but autonomous robotic operations. The MDF arm was chosen for this demonstration because it represents the implementation of teleoperation in space and can be readily used to demonstrate telerobotics as well. The MDF arm is a 1 G version of the shuttle RMS arm. Currently, the MDF arm is teleoperated with direct man or computer preprogrammed control and guidance.

TELEROBOTIC ARM DEMONSTRATIONS

This demonstration will use the existing MDF capability with a robotic tracker developed by McDonnell Douglas. This tracker will be used to process video camera inputs to determine target position, bearing, and attitude and to guide the MDF arm under operator supervision. The basic hardware elements and interface are shown in Figure 1. The robotic tracker will interface to the

MDF system through an RS232 link to the SEL 32/77 computer. The robotic tracker will be considered as a remote terminal and will input and display the following:

1. Input pitch, yaw, and roll and X, Y, Z data for operator command mode for MDF arm positioning.
2. Display data as the arm moves.

The tracker will also have the capability to perform command check and obtain response from the SEL 32/77 computer.

The crew station will initiate and stop operational commands as usual. The R12 panel will remain fully operational by being able to input pitch, yaw, roll and X, Y, Z data and perform command check.

This functional demonstration will perform manual target lock-on with autonomous target tracking, MDF arm guidance, approach, and positioning. The target range will be within 20 feet at acquisition. The target will be a standard grapple fixture target and will initially be stationary. The initial demonstration with a fixed lens camera will allow autonomous approach to about 3 feet.

TEST PROCEDURE

The MDF arm operator will position the camera to have the grapple fixture target in its field of view. The tracker operator will then place the acquisition gate about the target for lock-on by the tracker. After lock-on, the tracker will calculate the target position and input to the SEL 32/77 the new position (X, Y, Z) and attitude (pitch,, roll, yaw) to which the end of the MDF arm is to be moved. Initially, the tracker will estimate a straight line motion of the end of the MDF arm to the target with discrete movement increments of several feet. As confidence in the overall system operation is gained, larger increments will be allowed. For any movement to be executed by the MDF arm, the MDF operator must activate an execute control button on the R12 panel. After each arm movement, the tracker will calculate a new position and send it to the SEL 32/77 for execution until the camera is approximately three feet from the target.

DEMONSTRATION OPTIONS

After these static tests are completed, a series of moving target tests may be performed where the target will be moved to a new position after each arm movement. Also close in positioning (1 ft) with respect to the target will be performed as allowed by the availability of camera lenses and targets. Target engagement by telerobotic control is also being investigated using a compliant hand, which will incorporate vision based tracker guidance for approach to the target with force and position from the elements (fingers) of the hand for final target engagement.

MDAC TRACKING SENSOR

The architecture of the multimode sensor tracker is shown in Figure 2. The multiprocessor tracker is composed of three functional parts:

1) A Fairchild CCD 3000 camera and video processor
2) The MDAC 673 image and tracker processor
3) The Z8000 executive control processor

The video tracking functions are computation intensive requiring a high throughput special purpose signal processor. To match the video data with the bandwidth of the image processor, data compression is performed by the video preprocessor by either excluding regions of the scene that are of no interest or by performing a pixel averaging. This effectively performs video windowing and an electronic zoom. The preprocessor also performs a tracker controlled brightness and contrast adjustment to the video image. This enhances the tracker's capability to see and track the target.

The MDAC 673 is a high speed, 10 MOPS, special purpose microcodable signal processor. All tracking functions are performed in the MDAC 673. Existing algorithms are: (1) correlation, (2) centroid, (3) conformal gate, and (4) guard gate. The primary trackers required for these demonstration were the correlation and centroid trackers. The correlation tracker is a feature tracker that tracks by finding the best match of a video reference image with the scene. The centroid tracker is a contrast tracker that finds the center of the target exhibiting intensities above or below a controllable threshold. The conformal gate and guard gate trackers were required for countermeasure techniques or when the target background exhibited a lot of clutter. The conformal gate tracker is a statistical tracker that classified the scene as either background, target, or unknown. This tracker finds the target boundary and maintains the tracker gate size to enclose all of the target. The guard gate tracker detects when the target passes behind obstacles and controls the other tracker's operations while the target is not visible.

The Z8000 executive control processor directs the operation of the multimode trackers, provides operator interface, and controls the responses of the MDF arm. The executive processor controls acquisition of the target, monitors each tracker's aimpoint, and can reinitialize any tracker algorithm during the engagement. The operator interface is provided through the hand controller and the video monitor mounted on the tracking sensor.

The tracker configuration used in these demonstrations was developed in 1981. Upgrades to increase its computing capability, reduce its size, and lower its power consumption are being implemented. CMOS devices will be used allowing theprocessor speed to be increased from 5 to 10 MIPS for the array processor and from 300 KIPS to 1 MIPS for the executive processor. A floating point capability will be added. The pixel rate will be increased from 5 to 15 MHz. Several boards (video preprocessor and interface) will be reduced to a single 300 X 300 mil chip. Overall the power consumption of the packaged tracker will be reduced from 200 to 25 W and the number of cards from 11 to 5. It is anticipated that a version of this packaged tracker could be used in the Orbiter cabin.

COMPLIANT HAND

The MDAC-Compliant hand will consist of a drive unit, a pullmember, a strain sensor and segmented elements (Figure 3). The drive unit will be a brushless d.c. motor and a harmonic drive. The pullmember will be a metal cable within a cable guide. The sensor will be mounted between the motor and the end of the segmented elements to sense the pulling force of the pullmember.

The segmented element will be constructed of a number of individual links and compression springs. The pullmember will run from the pulley through the springs and through all links to the end of the element.

The brushless d.c. motor will rotate a pulley on its shaft to wind up the pullmember. The sensor will initially sense the resisting force created by the compression springs within the links and will feel a rapidly increasing force after contact with the target.

The MDAC segmented elements, however, have a number of individual links, which are separated by springs to average forces between links. It is this principle that gives our intelligent, sensor-controlled segmented elements the superior capability to accept an objects random curvature where each element develops its own shape. The number of links is not limited and all link dimensions are adjustable to create the best suited combination. The MDAC-Compliant hand (Figure 4) has four segmented elements and a palm camera for object identification and alignment control.

CONCLUSION

The capability of existing, packaged tracker and compliant hand hardware to perform telerobotic control functions with minor upgrades are functionally being demonstrated. Upgrades in hardware and software will be required to address the requirements of space operations. However, a great deal of the basic development have already been and are being performed and funded by other government agencies. This demonstration, with the 1 G RMS arm, will provide additional information on the integration of this technology with existing systems for near term robotic space operations.

ACKNOWLEDGEMENTS

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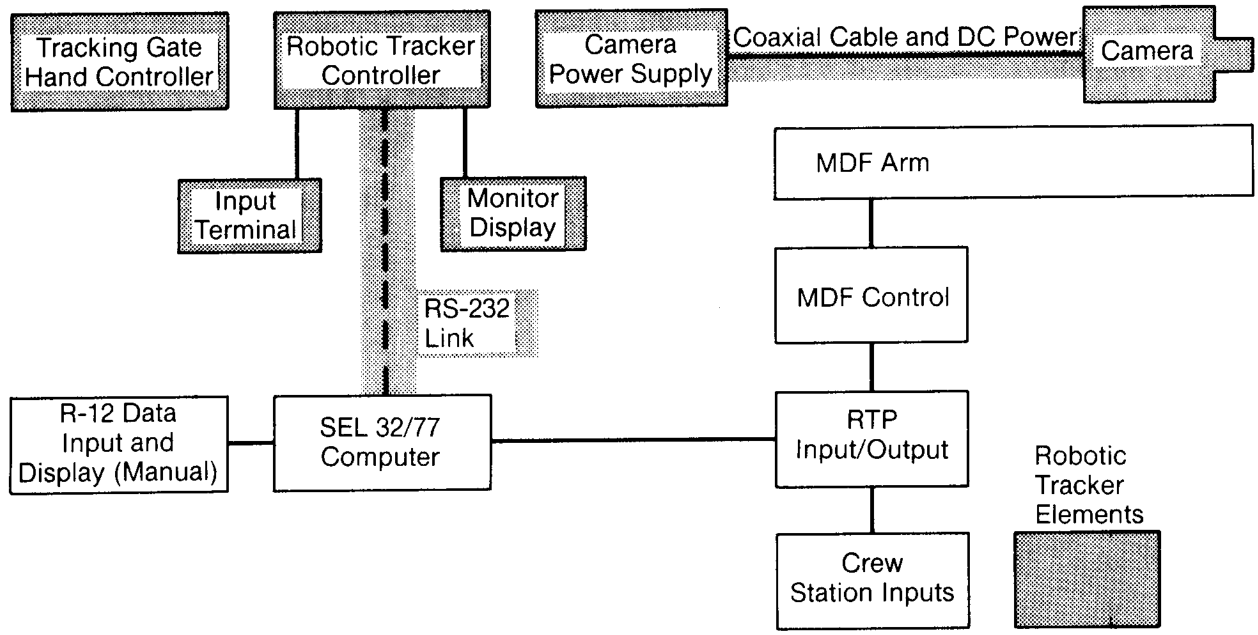


Figure 1. MDF/Robotic Tracker Hardware Elements

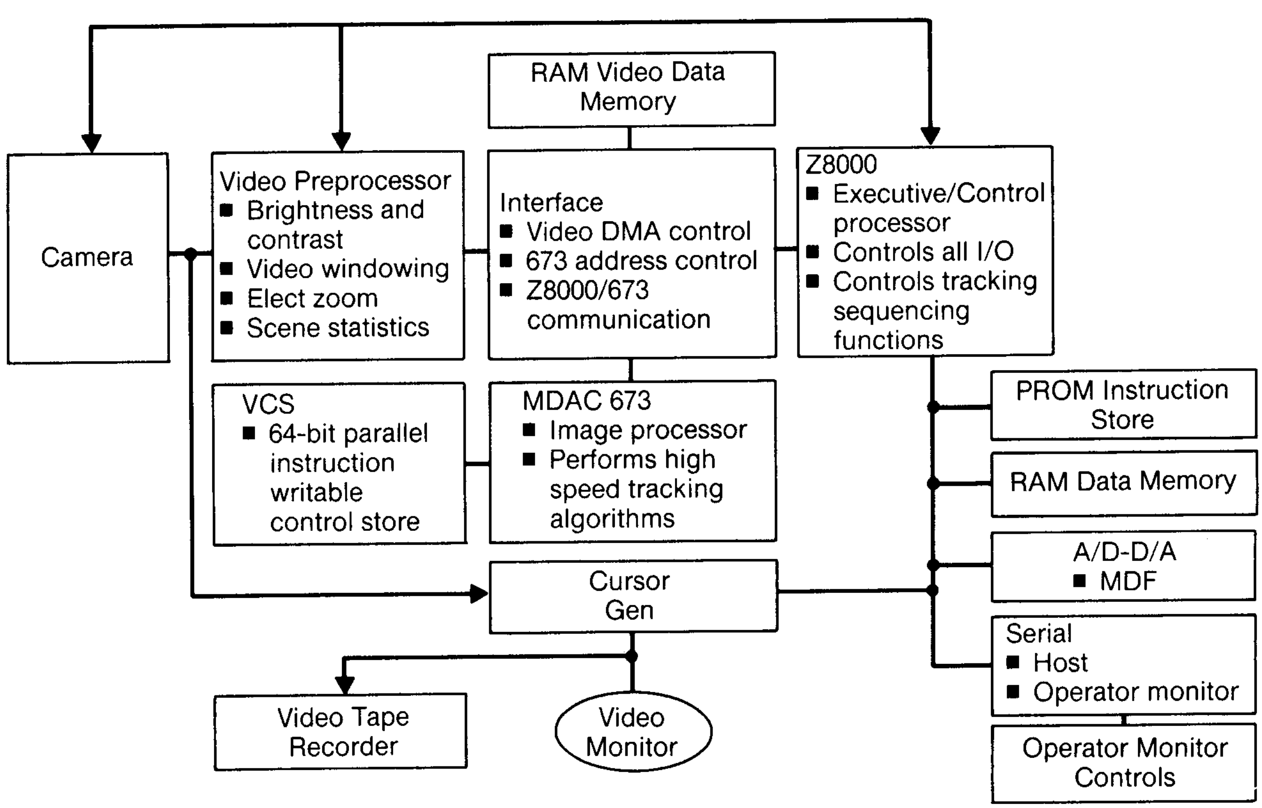
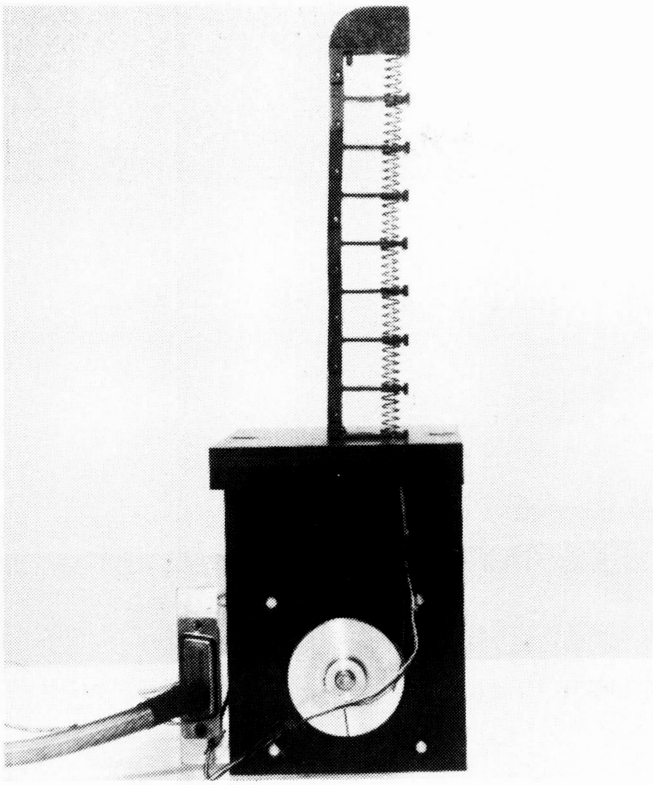
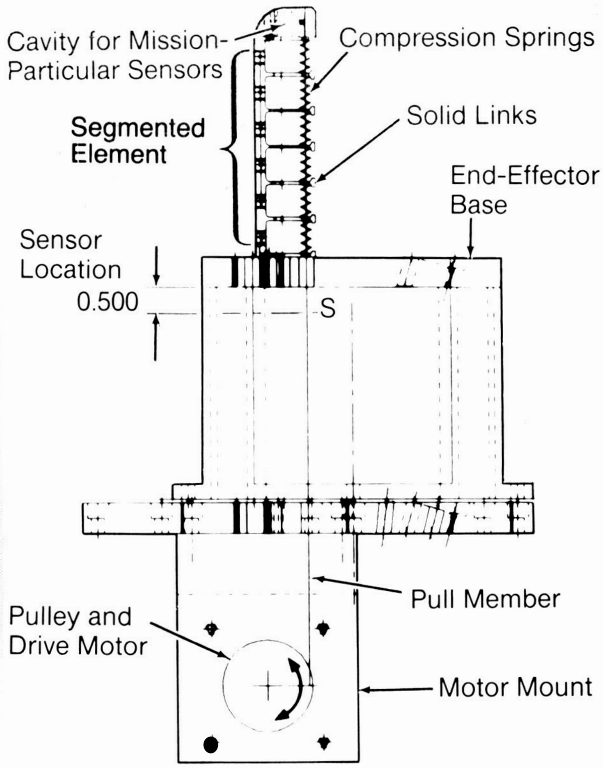


Figure 2. Architecture of the Multimode Tracker



Test Model of Single-Axis End-Effector (Extended)



Drive Schematic

Figure 3. Segmented Element Drive

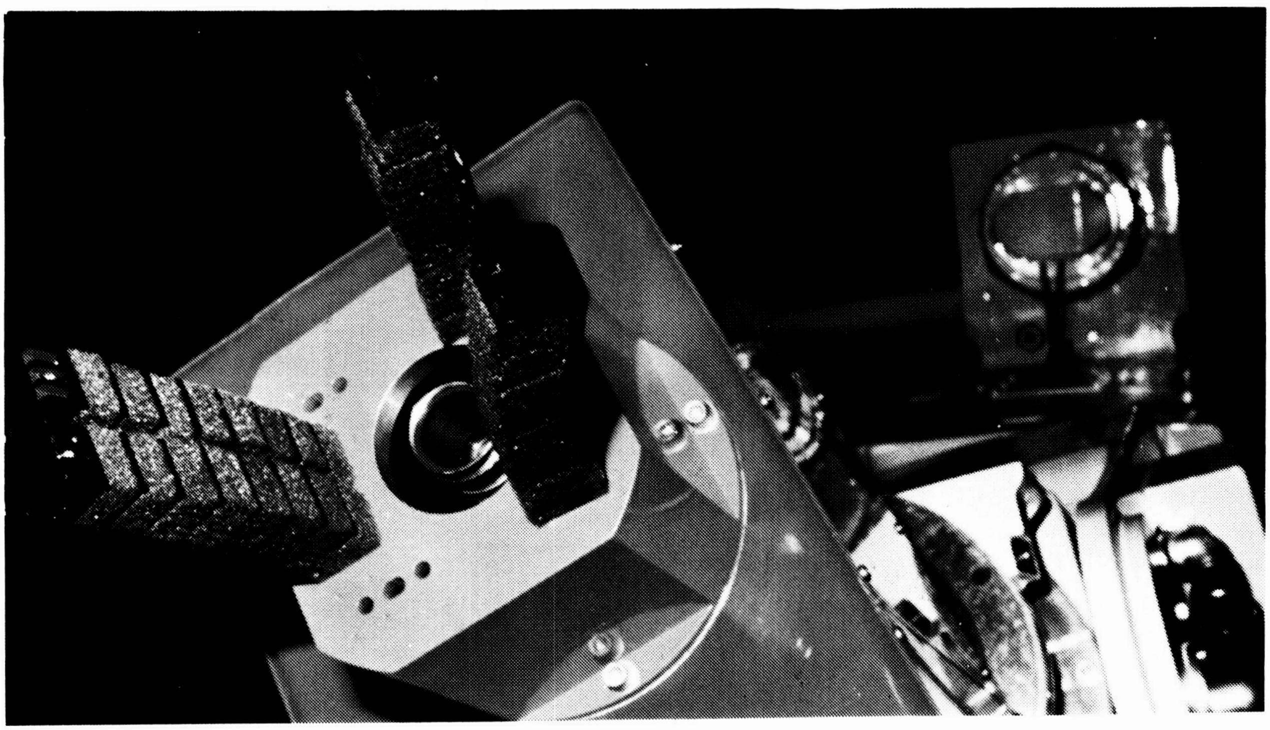


Figure 4. MDAC Compliant Hand With Four Segmented Elements and Palm Camera